## XLVIII.—*Further Observations on the Distinctive Characters, Habits, and Reproductive Phenomena of the Amœban Rhizopods.* By G. C. Wallich, M.D., F.L.S., &c.

[Plate VIII.]

In order to show the fallacy of regarding mere external modifications of the sarcode-substance as indicative of specific individuality amongst the Amœban Rhizopods, attention was directed in my previous papers to the intimate relation existing between such modifications and the varying nature of the conditions by which most of these lower forms of animal life are surrounded. I have now to offer the following observations in support of this view.

Whilst describing the singular phase in the history of *Amœba* whereby, in common with many of the more highly organized Protozoa, it survives the contingencies to which it is exposed through the drying up or deterioration of the medium it inhabits, I mentioned having detected, amongst certain confervoid matter, an abundant brood of this organism, and that in it were embodied the collective characters of numerous forms whose specific distinctness had been based almost entirely on the characters of their pseudopodia. The specimens alluded to, in conjunction with some obtained from other sources, afford excellent illustrations of the incidental nature of these varieties, and seem to furnish conclusive evidence not only that the figure assumed by the pseudopodia is subject to such a degree of variation as to become valueless as a distinction between the Amœban species, but that the extent of the variation is so great as even to invalidate the boundary-line between *Amœba* and *Actinophrys,* in so far as it depends on the character in question.

This view may, at first sight, appear overstrained; for I confess that, in my own case, nothing short of the constant repetition of the appearances through an extended series of specimens could have induced me to entertain it. It is true, moreover, that the transition from the form of pseudopodium said to be typical of *Amœba* to that held to be typical of *Actinophrys* had not previously been noticed by me with anything like the same distinctness. But, in the material under notice, the specimens exhibiting the transitionary characters were so numerous, the alternation of the characters so frequent, and the type assumed so well sustained, that, should the case be deemed exceptional, it ought certainly to be regarded as one of those very important exceptions that disturb the established rule. And hence, admitting the accuracy of the facts recorded, namely that, under any circumstances whatever, a true *Amœba* possesses the power of projecting from its surface the tapering and pointed pseudopodia of *Actinophrys*—that these pseudopodia are for a time rigid—that occasionally they are bent at an angle, and again straightened—that sometimes, though rarely, they coalesce with each other—that they are retractile into the parent mass—that, within a period ranging from a few minutes to a few hours, the whole of these pseudopodia may vanish and give place to the lobose and polymorphous pseudopodia of *Amœba*—and, lastly, that the organism is stamped as a true *Amœba* by the presence of the villous appendage, the characters of the nucleus and contractile vesicle, and the definite differentiation into an anterior and posterior portion—I say, admitting the accuracy of these facts, it is impossible to regard characters based on the figure of the pseudopodia as of distinctive value either in the case of species or of genera, in default of other and more important structural peculiarities.

The following are the more detailed particulars of the transition in question. In the 'Annals' for June last, a figure was given of a specimen of *Actinophrys* under distention by a large *Pinnularia* (see Annals, June, Pl. X. fig. 4)—a remark being appended to the effect that it would be difficult to distinguish this form from an *Amœba* on the retraction of the pseudopodia. No contractile vesicle was noted, but oil-globules were present within the protoplasm of the diatom. For reasons to be given hereafter, it is most probable that the figure is really that of an *Amœba* in the state preparatory to encystation, and that the specimen was of a similar nature to the one figured in the plate appended to this paper (Pl. VIII. fig. 12), inasmuch as the pool in which it occurred, like the pool in which my recent specimens were found, was being rapidly dried up.

But by far the most striking examples of *Amœba* assuming temporarily the external characters of *Actinophrys* were detected recently. Whilst I write, they are still plentiful. They are of small size, rarely exceeding in length $\frac{1}{600}$th of an inch. Before the transition from their normal state begins, they exhibit every character of a small-sized but fully developed specimen of *Amœba villosa*—that is to say, a distinct villous tuft, a spherical nucleus enclosed within a hyaline zone, one or more active contractile vesicles, crystalloids, granules, and the usual lobose pseudopodia of the species. But from one portion of the surface we now see projected a group of short, tapering, pointed pseudopodia, which rarely curve, but bend freely on their axes like the spines of *Echinus*, although, of course, without a vestige of special structure. In short, they closely resemble the short ciliary appendages of *Plœsconia* or *Kerona*, without serving, as the latter do, for locomotion (Annals, April 1863, p. 290).

The pseudopodia, however, soon begin to extend, and finally cover the greater portion of the surface. As they increase in number, the power of locomotion and projection of the ordinary pseudopodia ceases; and ultimately the structure seems to undergo a period of nearly complete quiescence, during which the pseudocyclosis does not continue, and the alternating action of the contractile vesicle is very slowly carried on without removal from the villous region. (See Plate VIII. fig. 11.)

Lastly, after varying periods, these Actinophryan pseudopodia are, one by one, retracted into the substance of the body; locomotion recommences in the usual manner, and with it the pseudocyclosis; and we have again presented to us the entire characteristics of *Amœba villosa*.

Whether the transition between *Amœba* and *Actinophrys* is ever of a permanent nature there are no means of determining in the present state of our knowledge. But, although unable to perceive any valid ground for doubting its possibility, I would observe that the line of demarcation between the two genera is sufficiently marked to render it available for purposes of classification. In short, whilst the shape, dimension, and number of the pseudopodial processes appears to be determined, in a great measure, by accidental and varying conditions of the medium by which they are surrounded, their physiological characters remain nearly unaltered.

The prehensile faculty in *Amœba* and *Actinophrys* is very differently brought about in the two genera. In *Actinophrys* it is similar in kind, but far superior in extent, to that present in the Foraminifera and Polycystina, and is principally dependent on the adhesive viscidity of the ectosarc. In *Amœba*, the ectosarc possesses little or no adhesive power, except in the villous region, and an object is held or dragged towards the body simply by being encircled and then subject to the contractile action of the sarcode. Hence it is evident that the ectosarc of the villous appendage of *Amœba*, in which a powerful prehensile power resides, is not differentiated to the same degree as that of the rest of the surface. This fact, which analogy would lead us to expect (since it is only at the villous region that the contractile vesicle discharges itself, and effete matters are extruded), is strengthened by the near approach in character of the villi themselves to the ciliary legs of *Plœsconia* and *Kerona*, inasmuch as the latter organs are the only portions of these creatures in which the tendency to sudden solution of continuity is observable.

It is deserving of special notice, moreover, that the facility with which coalescence takes place between the pseudopodia, and the adhesive faculty of the ectosarc, are such mutually dependent conditions as to be inseparable. In *Lieberkuhnia*, the Foraminifera, and the Polycystina these characters are at a maximum; in *Amœba* they are at a minimum, and consequently denote the closeness of the relation existing between the degree of differentiation, as *thus* manifested, and the presence or absence of a nucleus and contractile vesicle.

The higher the degree of differentiation, or, in other words, the higher the grade of the organism, the more completely does amœbasis take place in it. In *Amœba,* which occupies the highest position amongst the true Rhizopods, the distinction between the external and internal portions of the sarcode-substance is at a maximum, and hence there exists an opposite condition to that present amongst the Herpnemata or lowest order (see 'Annals' for June, p. 439), and we meet with the smallest amount of inclination to coalescence and the least degree of adhesive viscidity of the ectosarc.

Lastly. And equally deserving of notice is the fact that the lower the degree of differentiation of the sarcode-substance, the more distinctly is the pseudocyclosis of granules observable, and the more completely does it approach and even involve the immediate surface of the pseudopodia—being dependent, as already shown by me (Annals, November, p. 332), not on a vital tendency to circulate inherent in the protoplasm or its granules, but on the inherent contractile power of sarcode, by means of which a constant interchange takes place between the interior mass and the external layer, and an equable distribution of nutritive material is secured in the bodies of the most rudimentary and testaceous types. When it is borne in mind that in none of the families of Rhizopods is the circulation uninterrupted, but that it not only continually varies in rate, but very frequently ceases altogether for a time, it will, I think, be allowed that any analogy between the phenomena and a special circulatory force is altogether discountenanced; whilst we further discern that the stoppage of a circulating granule, its occasional transfer from one pseudopodium to another, and its subsequent advance or retrogression towards the parent body (on which so much stress has been laid by those who advocate the operation of a special and true cyclosis) are ordinary mechanical results depending, in the first place, on the coalescence of adjoining pseudopodia, and, in the second, on slight inequalities in the rates at which the efferent and refluent streams of protoplasm are moving (see Annals, November 1863, p. 332)—the granule being, of course, borne along by the pseudopodium in which that rate is the greatest, without any reference to its direction.

Without embarking in a vain attempt to determine whether the actions of the Rhizopods are dictated by instinct or are to be regarded merely as the outward manifestations of a natural law impelling the animal organism to sustain existence and reproduce its kind, as it does the vegetable, I beg to direct attention to some singular facts, which throw light on the subject at the same time that they serve the more practical purpose of denoting the true characters of the phenomena to which they relate—premising that it will be a fitting period to discuss the question of instinct when we shall have become sufficiently acquainted with these lower forms to state, with any approach to accuracy, the relations and limits of those vital and physical forces whereby their functions are governed.

Both *Amœba* and *Actinophrys*, undoubtedly possess discriminative power in the selection of their food; that is to say, they do not incept every particle that happens to come in their way, organic and inorganic alike, but, generally speaking, only such substances as are best fitted for their nourishment, whilst they reject those that are not so fitted. It is true that inorganic objects are frequently present in the body of *Amœba*, which there is reason to believe have gained ingress accidentally. But, in most cases, the minute size of these objects, as compared with the organic food-particles associated with them, testifies to their having been admitted along with the latter, and not in lieu of them, or to their having been forced into the interior of the plastic mass of the creature whilst moving, as it constantly does, amongst organic and inorganic débris. The discriminative faculty, however, is exemplified in the most remarkable manner when one *Amœba* comes in contact with another, or with an *Actinophrys*.

Amongst the numerous instances in which I have seen *Amœbæ* come into contact with each other—whether in the course of their own movements or through any manipulatory effort on my part—it has not been my lot to witness the coalescence or fusion of two individuals, which has been regarded by some observers as a "zygotic" or reproductive process. On the contrary, such individuals, after remaining for a time in contact, have invariably "sheered off" from each other, under circumstances which proved that they were not inconvenienced by the restraint to which they were subject. In like manner, I have never seen the re-amalgamation of two or more portions of a divided *Amœba*. This is the more remarkable, since this phenomenon unquestionably takes place in *Actinophrys*; for, although the more viscid and adhesive quality of the ectosarc of the latter genus may, to some extent, account for the apparent anomaly, it can hardly be accepted as a satisfactory explanation of it.

In *Actinophrys*, the coalescence of two individuals, which is by no means of rare occurrence, has been repeatedly watched by me from beginning to end; and, with a view to ascertain whether the process was followed by any modification in the appearance of the sarcode-substance generally or the nucleus, specimens in which fusion had taken place, and which, owing to their very large size and hyaline nature, were admirably adapted for exhibiting any change, were kept carefully isolated in shallow glass cells for several days. In these examples, however, there was no other change observable than the increase in bulk, which dated, of course, from the time that fusion was complete.

Those who have watched the behaviour of *Actinophrys* when in search of food, are aware with what stolid but unfailing energy it frequently drags into its interior organisms not only superior to it in type, but in activity of movement. Yet, withal, it succumbs to *Amœba*. It is possible that the more rapid locomotive power of *Amœba* may serve in some degree to give it the mastery; but, on the other hand, there is evidently some other obstacle to an *Amœba* becoming a prey to *Actinophrys*, inasmuch as the largest specimens of the latter generally decline all contest with *Amœbæ*, even when sufficiently small to ensure their destruction were it a mere question of strength. When, by accident, the two organisms come into collision, the *Amœba* seems to be forthwith aroused to an unwonted degree of activity, and an effort is made by it to envelope the *Actinophrys* with the folds of its pseudopodia. Failing, however, in the attempt to secure the entire mass, the *Amœba* now employs its pseudopodia in tearing out portions of its adversary; and these are in due course consigned to vacuolar cavities. On one occasion I saw nearly half of a large *Actinophrys* transferred piecemeal, after this fashion, into the interior of its captor—the several fragments torn out (not simultaneously, but by a series of consecutive efforts) becoming rapidly absorbed under the digestive action to which they were immediately subjected (see Pl. VIII. fig. 18). In so far, therefore, as it is legitimate to draw conclusions from appearances and the behaviour of the organisms in question, instead of confirming the opinion as to their betokening a reproductive act, they tend rather to show that, between the so-called zygosis of two specimens of *Actinophrys* and the inception of an *Actinophrys* by an *Amœba*, there is but this difference—that in the one case the act is akin to cannibalism, whereas in the other it is not so.

In tracing the development of the young *Amœba*, either from the free sarcoblasts or large mulberry-shaped masses that resemble acapsular nuclei, the different steps are essentially similar. They would seem, in the first place, to be associated with an increase of the more fluid hyaline protoplasm within which the granules of these bodies are suspended, and which may increase to any extent without any alteration taking place in its initial character. The sarcoblast and mulberry-mass alike have no capsular investiture, but are supported by the layer of ectosarc into which the surface of the protoplasm is differentiated. But, prior to the first stage of development about to be described, amœbasis does not take place; that is to say, the outer layer is consolidated by mere contact with the medium around, but the reciprocal interchange between it and the endosarc has not as yet received its first impulse. This impulse consists in the evolution of one or more contractile vesicles, which make their appearance in the interior, but whether at any definite point I am unable to determine. At first extremely minute, the contractile vesicles gradually increase in size, causing the entire body to enlarge materially, but without as yet impairing its perfectly globular figure (Pl. VIII. figs. 1 to 3, 6 & 7). In some cases two or even three of these vesicles appear; but, as the increase in the protoplasmic substance is uninfluenced by that of the vesicles, it frequently happens that the latter constitute as much as four-fifths or five-sixths of the contents of the spherule. It is during this distention that the minute nucleus, previously absent or obscured by the closely compacted nature of the granules in the sarcoblast or mulberry-mass, may be seen. Of course, up to this point the young *Amœba* is motionless, and without the faintest trace of internal circulation, except in so far as the gradual distention of the contractile vesicles causes the granules of the protoplasm to shift their positions. In short, the organism consists essentially of a quiescent spherical globule of sarcode containing granules, a contractile vesicle, and a nucleus.

The second and most important stage now commences. The tension to which the ectosarc is subjected by the endosmotic enlargement of the contractile vesicle, causes it to yield at a certain point; the spherical outline is at once destroyed by the projecting portion of the vesicle (Pl. VIII. fig. 4). The latter bursts, for the first time, through the ectosarc, leaving behind a minute mammilliform projection which constitutes the first rudiment of the villous appendage*. Should more than one contractile vesicle be present, it is invariably urged, by the contractile effort now made, towards the same point to discharge itself; and from this time the discharge occurs only in this region. But polymorphism has now set in. The little machine has been put in motion,

* In the 'Annals' for June (Plate X. fig. 8), I figured a minute spherical *Amœba*—one of the few I had then seen, and regarded by me as a "gemmule." I had not witnessed the detachment of these from the parent mass. This specimen exhibits a "mammilliform process" at one portion of its periphery, which was evidently the site of discharge of the contractile vesicle, although not recognized by me as being of this nature.

as it were, by the artificial impulse received on the discharge of the contractile vesicle; pseudopodia are projected and withdrawn, and, as a necessary consequence of these movements, pseudocyclosis goes on; food-particles are incepted, effete matter extruded at the point of *least* resistance—namely, in the midst of the villous organ; and, following as a natural result from these combined changes and the more subtle actions they involve within the body, the phenomena of amœbasis are established (see Plate VIII. figs. 4 & 5).

Although it would appear, at the first glance, that the villous appendage constitutes the most highly differentiated portion of the Amœban structure, since the contractile vesicle invariably discharges, and all effete objects are extruded, in its midst, the reverse is probably the case, inasmuch as, the continuity of the endosarc in this region being constantly disturbed by the causes just named, time is not allowed it to attain the same degree of consolidation that is attained by the rest of the surface. It must be borne in mind that the coalescence of the pseudopodia is rare in *Amœba*. Indeed it hardly ever takes place except under an effort to envelope some living object, or when the surface is broken, and a portion of the ectosarc driven back along with it into the interior of the body*, by the admission of some large food-particle.

But inasmuch as inception of food is only an occasional act, the disturbance of the ectosarc, which is its necessary consequence, must also be occasional. On the other hand, the contractile vesicle is constantly discharging itself at a single spot, namely, in the midst of the villous appendage; and it is here that the effete residue of every object incepted, either for food or by accident, is extruded. Moreover, whilst the inception of a food-particle can very rarely take place twice consecutively at the same spot, every act of extrusion does so; and this being the case, it is easy to perceive why the consolidation of the external layer of sarcode (ectosarc), being the result of contact with water, and dependent in degree on the period of exposure, should be greater in every other part of the body than in the villous region.

Again, it thus becomes easy to understand why the contractile vesicle discharges itself, and effete matters are extruded, in the villous region. It has been shown that the circulation of the contents of the sarcode-body is not a special vital act, but due to its polymorphism. Now contractility is the inherent property

* On two occasions I have seen a full-grown *Arcella* so incepted, not through an *aperture* extemporized, but evidently in the same way that a small object, if pressed against an inflated caoutchouc capsule, would push before it a portion of the wall.

of sarcode, but not till it has become consolidated to a certain extent; and this consolidation does not take place within the substance, but only at the surface. If we take the example of an ordinary contractile substance, the process is to all intents the same. Thus caoutchouc, when oozing from the parent tree, is not contractile, but a semifluid adhesive mass. So is the sarcode of the interior of an *Amœba*. But as soon as the action of the atmosphere causes coagulation or consolidation of the caoutchouc tears, the innate contractility becomes at once manifest. A precisely similar effect is produced by the contact between the endosarc and water.

It is quite evident that in the case of caoutchouc, the consolidation once produced, there is no return to the previous condition. Why? simply because its vitality ceased with its extrusion. But even here the analogy is not altogether destroyed; for the contractility of the caoutchouc may be materially diminished by heat, and it may again become an adhesive semifluid mass, capable of permanently assuming any figure. Yet, on reduction of the temperature, again consolidation takes place, and with it the mass resumes its elasticity. So that, assuming sarcode to be endowed with vitality—a fact, I presume, not admitting of denial—and also that it is contractile, we have not only all the conditions that place the phenomena observed in the light of simple cause and effect, but it appears to me obviously impossible to account for them in any other rational way.

In the 'Annals' for June (p. 451) a cursory allusion was made to two varieties of the common *Difflugia proteiformis*, which were present in the Hampstead pools. These varieties afforded good illustrations of the tendency of the test to undergo considerable modifications in shape and likewise in the disposition of the extraneously derived materials of which it is for the most part built up. It was stated that whereas the basal substance, with which the sandy particles commonly present in the test are cemented together, is secreted by, or, to speak more correctly, is an exudation from, the animal, examples are frequently met with in which there is no readily appreciable intermixture of mineral particles, and the entire test would seem to be composed of almost colourless pellets, differing only from those seen in the tubes of *Melicerta* in their shape and freedom from colouring matters. These pellets are minute cylinders having rounded ends. They are occasionally straight, occasionally more or less curved, and vary in length from $\frac{1}{5000}$th to $\frac{1}{3000}$th of an inch, whilst their diameter varies from $\frac{1}{20000}$th to $\frac{1}{10000}$th of an inch. They are distributed over the surface in a single layer, the larger and smaller pellets being made to fit to each other. Some specimens, however, are built up partly of these pellets and partly of sandy particles combined; whilst others appear to have one portion of the test built entirely of pellets and the other entirely of sandy particles. But the polariscope enables us to perceive that in nearly every specimen the basal layer of chitinous matter is strengthened by delicate films of mica, and that the external wall, whether formed of coarse sandy particles or pellets, is superimposed upon it. This structure of the test is to be traced in the curious variety of *Difflugia proteiformis* alluded to by me in the 'Annals' for June (p. 451, pl. 10. fig. 12) as being remarkable on account of the development of a septum between the main cavity of the test and its broad tubular neck, which causes it to resemble the two earliest chambers of the shell in *Miliola*. But one and all of these modifications, as before stated, are manifestly confined to the test, and in no appreciable manner associated with equivalent differences in the animal mass.

During the past summer and autumn, the same forms have been met with by me very generally in boggy pools—merging, on the one hand, into the "pyriform" variety, both with and without the little apical appendage of the test, and, on the other, passing into the equally common subglobular variety.

I have now to notice two still more aberrant forms recently obtained from the Hampstead pools. Of the first of these, only a single specimen has as yet presented itself from that locality. I had previously, however, met with one or two nearly similar specimens in a boggy streamlet on the west coast of Greenland*. Owing to the extraordinary transparency of the Hampstead specimen, which was still alive when examined under the microscope, it afforded a good opportunity for the detection of any novel characters within the sarcode-mass, had these existed. The pseudopodia were finely granular, free from incepted matters, and more or less cylindrical and lobose as in the ordinary *Difflugiæ*; the sarcode-substance charged with variously coloured food-particles; the nucleus spherical, apparently homogeneous throughout, and sustained in the usual hyaline cavity towards the fundus of the test; whilst the contractile vesicle was single, and, although partaking in the movements within the test dependent on the protrusion and retraction of the pseudopodial processes, returned to discharge itself, as in *Amœba*, at the posterior portion of the body. So that the characters are identical with those of *Difflugia proteiformis*, although, owing to the irregular structure of the test in that species, they are observable with much greater difficulty, and hardly ever simultaneously as in the present example.

* A figure of the Greenland *Difflugia* may be seen on reference to Part I. of 'The North Atlantic Sea-bed' (pl. 4. fig. 17).

It is in the configuration of the test, however, that the most striking peculiarity occurs. In figure it is like that of the pyriform variety of *D. proteiformis*; but, instead of being built up of irregular mineral particles, so as to present a rugged outline exteriorly, it was entirely composed of hyaline rectangular plates, arranged with the greatest regularity in consecutive transverse and longitudinal series—the smaller plates being disposed at the two extremities, whilst the larger ones occupied the central and widest portion of the structure. This specimen is represented, in its mounted state, in the plate appended to this paper (fig. 16), under the name of *D. proteiformis*, var. *symmetrica*.

Of the chemical composition of these remarkable rectangular plates I am as yet unable to give any definite account. But there is some reason to believe they are crystalline and siliceous in their nature,—in the first place, from the perfectness of the angles and their resisting the effects of the heat to which the specimen was subjected during mounting in balsam; and in the second, from their exhibiting no coloration when seen with the aid of the polariscope.

The second aberrant form, however, involves not the test, but the animal inhabiting it, at least so far as the preponderance of evidence goes, and is in fact but an example of the transition, in a testaceous Rhizopod (namely, *Difflugia proteiformis*, var. *acuminata*), of the typically lobose pseudopodia into those of an *Euglypha* or *Gromia**.

In the specimen under notice, the large and coarse sandy particles entering into the formation of the test completely precluded observation of the characters of the soft parts within. But it is almost unnecessary to point out that, whatever these may have been, if betokening a *Gromia*, the test must be regarded as abnormal; if a *Difflugia*, the pseudopodia must be so.

It is well known that the *Amœbæ* are generally to be found in shallow pools or streamlets, more or less charged with disintegrating organic matter, and liable to stagnate, or to become altogether dried up, by periodical failure of the water-supply. I say, charged more or less with organic matter *undergoing* disintegration, because it is an error to suppose that the *Amœbæ*, or indeed any of the Rhizopods, are able to continue existence long in water which has parted with its oxygen to the extent of be-

* I may repeat in this place the statement made in a former communication (Annals, August, p. 123), that I had detected a distinct nucleus in *Gromia oviformis*, and at a later period, but only once, an equally distinct contractile vesicle. But, until further opportunities present themselves of determining whether or not these organs occur universally amongst all the members of the genus, I would reserve my final opinion on the subject.

coming putrescent. The decadence of every Rhizopod dates from the commencement of this process; and there seems reason to believe that the putrescence of the medium in which they live is the only condition against which nature has furnished them with no safeguard—in short, that the entire extermination of the brood takes place whenever such putrescence has become fairly established.

Some of the aspects under which the *Amœbæ* resist partial, if not complete, desiccation have already been noticed. The following additional example, however, has a twofold interest; for, on the one hand, it illustrates the nature of the relation between the animal and the state of the medium by which it is surrounded, and, on the other, serves to explain what has long been regarded by myself, and probably by many other observers, as a very anomalous occasional condition of the Diatomaceæ.

Some Diatoms would seem to be endowed with an increased motile power, to assume a deeper colour from the inordinate thickening of the endochrome-layer, and to generate an undue quantity of oily matter, as soon as the water sustaining them begins to be putrescent. Their healthy growth and multiplication are inseparably associated with an abundant supply of oxygen and light. In common with the rest of the lower Algæ, they are frequently to be found in the same localities as the Amœban Rhizopods; and, like the latter, they are provided with special means for resisting the extinction of their kind to which they are consequently liable. But at a certain point, although by no means so readily as the Rhizopods, they succumb in like manner to the action of putrescence; and it seems probable that the increased motile power and accumulation of endochrome referred to are evidences of an expiring effort to tide-over this condition, should it prove of a transitory nature.

Some species certainly resist decomposition more successfully than others; but there is no ground for supposing that this increase of power signifies anything more than habituation to conditions to which other species, or the same species when inhabiting localities uninfluenced by such conditions, are not amenable. The genus *Pinnularia* affords a notable example of the kind, both from the circumstance of its occurring in the same habitats as the Amœban Rhizopods, and from its being frequently of a size to render it admirably fitted for observation.

The appearances about to be described have been seen by me, not only in this country, but in the tropics and sub-Arctic regions, always, however, in streamlets and pools such as those referred to, and in connexion with Naviculoid Diatoms, as for example, *Pinnularia, Epithemia, Navicula, Stauroneis,* and more recently *Nitzschia*; so that they are by no means uncommon. I allude to the enclosure of one or more of these Diatoms within a distinct capsule, which it has been customary to regard as indicative of encystation, connected either with the production of its sporangium or with some heretofore unrecognized reproductive process.

The frustules, when simply surrounded by this capsule, and nearly altogether deprived of their soft and coloured contents, could hardly convey any other impression than that they are undergoing one or other of these processes; for there are no characters discernible in the capsular investiture whereby its real source and function could be determined. And, coupling the undoubted faculty possessed by the Diatomaceæ, of occasionally secreting in augmented quantity the gelatinous film by which they are normally surrounded at all times, with the occasional imprisonment of more than one frustule, it is only necessary to assume that the external layer of this film becomes consolidated, and the appearances would seem to be sufficiently accounted for. But wherever the distinct capsular investiture is present, for reasons now about to be adduced, such an explanation would appear to be erroneous, and the condition described to be dependent on animal, and not on vegetable, agency. In short, an *Amœba* has become encysted, and not a Diatom*.

In the course of some experiments on feeding freshwater Rhizopods by artificial means, towards the close of last month (October) my attention was particularly drawn to this subject on perceiving that in some of the Hampstead material then freshly procured, but nevertheless presenting traces of disintegrative decay, a large proportion of the *Amœbæ* were distended (as in the case of some of the specimens referred to in my paper of April last) with frustules of *Pinnularia*, and that, whilst these *Amœbæ* were rapidly ridding themselves of the rest of their extraneous contents, they appeared to select and retain those frustules which were most copiously charged with endochrome and oil-globules, and to be gradually assuming a consolidated investing layer.

The artificial food employed consisted of weak solutions of gum and gelatine. Deeming it possible, however, that the intermixture of these substances with the water containing the *Amœbæ* might have something to do with the encysting process

* In speaking of the solitary example of an encysted *Amœba* recognized by me at the time my observations contained in the 'Annals' for May (p. 368) were written, I was unaware that Schneider had pointed out the occurrence of a "resting-stage" in the history of *Amœba*. This writer distinctly refers to the formation of a membranous sac, although he failed to trace the encysting process beyond this point. My observations on this head, in the last Number of the 'Annals' (p. 334), ought, therefore, to be regarded as supplementary to and confirmatory of his.

and the singular features the specimens assumed, a fresh supply was obtained from the same locality. This was retained in its natural state, and on examination was found to contain specimens in every respect similar to those described as occurring in the mixed material. The encysting process was thus shown to be in no way dependent on conditions artificially produced, but to be the result of an effort on the part of the creature to furnish itself with nutritive matter during the development of the sarcoblasts into which the sarcode-mass is destined, under these circumstances, to resolve itself*.

The first step, as already stated, consisted in the extrusion of all foreign particles besides the diatom-frustules—the vacuolar cavities in which the latter were enclosed being, for a time, distinctly visible and often of great size (see Pl. VIII. figs. 12 & 13), but gradually disappearing as their fluid contents became absorbed. Finally, all trace of pseudopodia, nucleus, contractile vesicle and villous organ vanished; all motion to and fro, and the pseudocyclosis dependent on it, ceased; and the diatoms seemed to be merely surrounded by a layer of coarsely granular but otherwise homogeneous sarcode, the outline of which was preserved by a distinct capsular wall, whilst its shape was dependent on the disposition and number of the enclosed frustules.

It may be remembered that (in the 'Annals' for June, p. 435) it was stated that the bodies to which I had given the name of sarcoblasts, and described as being "distinctly granular, nearly homogeneous throughout, and devoid of cell-wall," in all probability "perform some important part in the process of reproduction, and are identical in all save colour with those of the Foraminifera, Polycystina, Thalassicollidæ, and some other pelagic families;" whilst in a still more recent paper ('Annals,' August, p. 125) I mentioned that "in the earliest recognizable condition in which I had found the Polycystina and Acanthometrina occurring as independent free-floating organisms, their rudimentary shell or framework had invariably been enveloped in bodies precisely resembling the sarcoblasts of the mature forms," and that to this extent their share in the reproductive process had been traced out.

The views then expressed receive the most complete verification from what takes place in these *Amœbæ*. The movements both

* It is worthy of record that no organisms but Diatoms have been found by me in these *Amœba*-cysts, notwithstanding the circumstance that, when decomposition was commencing in the pools, many of the lower vegetable forms, such as *Closterium, Volvox, Gonium,* and the host of minute phytospores that have so erroneously been regarded as mature *Desmidiaceæ* were in profusion.

within and without their bodies, although energetic when the encystation commenced, are succeeded by a state of complete quiescence afterwards. But, even at this stage, clear proof of vitality is afforded by the gradual segregation of the granular particles into masses, which ultimately become spherical and apparently identical with the sarcoblasts (Pl. VIII. fig. 14). Of course, if identical, my view as to these bodies being formed from the granular particles of the endosarc generally, rather than from the repetitive subdivision of the nucleus and its capsule, receives confirmation*. But, under any circumstances, it is now manifest that the sarcoblasts are true reproductive bodies, inasmuch as, although I have not hitherto detected the passage of a sarcoblast into a young *Amœba* whilst yet within the *Amœba*-cyst above referred to, or within the frustule of the diatom (where the sarcoblasts also occur under certain conditions to be detailed immediately), I have traced the development of the young *Amœba* from bodies identical with them in appearance, and occurring in a free state in the same medium and at the same time.

But to return to the history of the sarcoblasts whilst yet within the *Amœba*-cyst. When fairly formed, only a few isolated granules are to be seen associated with them—the endochrome of the diatom having become shrivelled and discoloured, and nothing remaining to indicate the true origin or office of the capsule.

The most remarkable feature, however, has yet to be noticed. The *Amœba* occasionally seems to obtain an entrance into the interior of the diatom-frustule, either during or after the appropriation of its contents—but probably after, for reasons which will presently appear. As already stated, sarcoblasts are occasionally to be met with within the frustular cavity. When this happens, ingress has not been effected through any normal apertures that exist in the structure, but through the partial dehiscence of the two valves at one extremity; whilst the dehiscence is, in all probability, connected with the presence of the *Amœba* to this extent only, that on the protoplasmic substance being abstracted which serves as a support for the valves and connecting zones, these fall asunder, and an opening is thus established (Pl. VIII. fig. 15).

The greatest number of sarcoblasts seen by me within an *Amœba*-cyst was eight; but generally it did not exceed half that

* It is possible that the granules entering into the formation of the nucleus, and which are undistinguishable, when isolated, from those of the sarcoblasts, under any circumstances may have become diffused through the endosarc generally. Hence my view as to the mode of formation of the sarcoblasts and their non-investiture by a capsule receives corroboration.

number; whilst within the frustule I have not seen more than four.

In directing attention to these facts, I would lay great stress on their bearing upon the question as to whether true *Amœbæ* are ever developed within the cells of the confervoid Algæ. For, although I have hitherto failed to trace the passage of the sarcoblasts into a young *Amœba* whilst yet within the interior of the diatom-frustule, it is evident that if the granular bodies, within and without the frustule, are identical in origin (and I see no reason for questioning it), the actual witnessing of the process is a mere matter of time and patience; and it must be obvious that, in the absence of a previous knowledge of the origin of the intrafrustular *Amœbæ*, the great error would in all likelihood be perpetrated of regarding them as having been generated from the gonidia of the Protophyte, instead of from the sarcoblast of the Rhizopod.

It is necessary to mention that the mere occurrence of a few more or less colourless granular corpuscles within a capsular cavity affords no evidence either as to their origin or their nature. Such bodies are produced both in the animal and vegetable kingdoms, and may constantly be detected within the effete tests or skins of Infusoria, Rotifera, Entomostraca, and confervoid Algæ. In most cases, their presence is purely accidental, or at all events unconnected with the reproduction of the organism within whose test or cell-wall they are found. So that the establishment of the fact I have just recorded teaches us how great a degree of caution is requisite before we pronounce vegetable products, found within the bodies of the lower forms of animal life, to have been evolved there; whilst, on the other hand, it exemplifies how subtle are the means whereby animal germs may find their way into, and hence simulate, vegetable products.

Here then we have presented one phase, at least, of the encystation of *Amœba*, from its commencement to its completion. The supplementary phenomena—namely, those dating from the partial desiccation of the granular bodies now formed, to the period at which they become developed into young *Amœbæ*, have been traced in my last paper on the subject (Annals, Nov. 1863). In interpreting the appearances, I have only to add that the abundance of the specimens, and the successive stages of the process observed, render it tolerably certain, on the one hand, that the protoplasm of the diatom furnishes nutritive material to the Rhizopod during the period of quiescence attendant on its encystation; on the other hand, that the occasional enclosure of frustules belonging to distinct genera—as, for example, a *Pinnularia* with a *Stauroneis* or a *Navicula*—

renders it certain that the presence of the diatoms is in no manner connected with *their* encystation or reproductive processes.

Assuming then, as I believe there is every reason for doing, that the Amœban Rhizopods are hermaphrodite, but leaving for future and much more extended research the determination of the male and female elements, with the precise method in which the impregnation of the latter is effected, I think we are fully warranted in recognizing the operation of no less than three apparently distinct modes in which a new brood may be developed, and in regarding this singular feature in their history as a provision for the perpetuation of the species, without reference to the stage of development at which the parent may have arrived when it happens to be destroyed.

The following are the three modes of *reproduction* in question:—

I. By extrusion from the body of the parent of a minute individual already perfect as regards the essential characters of the species.

II. By development, singly, from one of the sarcoblasts, or acapsular nuclear masses, which are formed within the body of the parent either prior to or during the process of encystation.

III. By development, singly, from each of the granules of the acapsular nuclear masses, on the disruption of the latter.

Whilst the *multiplication* of the individual, or, to speak more correctly, the vegetative repetition of the species, may be brought about,

I. By the disruption of the parent body into two or more parts, each capable of maintaining an independent existence.

II. By gemmation, or the evolution, from some portion of the surface of the parent, of a "gemmule," destined ultimately to assume the characters of the species. This last process I am unable to vouch for on my own authority, except as regards *Actinophrys*.

Assuming, then, that the evidence adduced throughout the previous and present communication establishes the fact that the differentiation into ectosarc and endosarc is of the kind indicated—that is to say, a process involving the increased consolidation of the external layer by the operation of physical agencies on living sarcode, whilst the reconversion of this external layer, and the constant interchange taking place between it and the more fluid mass within, coupled with its inherent contractility and extensibility, are the essential attributes of this substance—is it possible to account for the appearances attending the inception and extrusion of foreign matter, the formation of vacuolar cavities, the multiplication of the contractile vesicles, their division, reunion, circulation through the body, and invariable discharge in the midst of a definite and very limited area, under these circumstances? The answer of those best able to judge will, I hope and believe, be in the affirmative. At the same time I am fully prepared to encounter the opposition to my views regarding the nature and properties of sarcode which is inseparable from preconceived notions handed down from writer to writer, as it were traditionally, and by many persons accepted without question, in defiance of their inexplicable character *; for it is but requisite to look attentively into the statements that have been put forward on the subject, to discern that they involve agencies and effects not only exceptional as regards the lower forms of animal life, but exceptional as regards the known laws of matter, whether organic or inorganic †. On the other hand, I again submit that the explanation here offered is not a bare hypothesis, the accuracy or fallacy of which there are no means of testing, but one following legitimately on the recognition of causes that contravene no established laws, and are reconcilable with the phenomena observed in the particular class of structures it has been my endeavour to describe.

*Note.*—It is necessary to state that, whilst the figures appended to the present and previous papers are copies of sketches taken, by the side of the microscope, during actual observations (and I guarantee them to be as accurate as it is possible to make figures that represent living and moving microscopic structures), the facts recorded are the result of examinations occupying from four to seven hours daily, and continued for a period of eight months. I mention this solely for the information of those who are not well versed in tracing out the physiological phenomena of organisms that reveal their workings so capriciously as the Rhizopods. But although the first detection of such phenomena could hardly accrue without this labour, their re-detection may be secured much more readily. No expenditure of time, however, devoted to the exploration of a field so rich, and so fitted to assist us in arriving at a better knowledge of the higher forms of life, can be too great.

Kensington, November 20, 1863.

* One of the most distinguished of the Continental writers on microscopical anatomy (Kölliker) does not hesitate to declare that the method in which *Actinophrys* incepts and rejects food is "almost a miracle."

† The most singular feature in the discussion on the properties of sarcode is, that those observers who insist most strongly on *a definite and permanent membranous* ectosarc in *Amœbæ* find no difficulty in reconciling its existence with the constant lesions it must of necessity be subject to through the above-mentioned inceptions and rejections

### *Postscript.*

The experiment about to be recorded was brought to a close after the preceding pages were sent to press.

On the 27th of last month, a small quantity of the confervoid material, which had previously been kept in water for several weeks, and contained living *Amœbæ* in abundance, was placed on a plate of glass, covered by a bell-glass, and permitted to dry within doors by evaporation. On the 29th ult. all trace of moisture had vanished, the mass forming a dark-coloured hardened film, which it was difficult to remove. On the 18th of the present month—that is to say, after having been subject to complete desiccation for twenty-one days—the plate of glass was placed in a saucer and covered to the depth of half an inch with distilled water. It remained in this till last evening, when, on examination under the microscope, the confervoid substance was found to contain numerous minute *Amœbæ* just evolved from sarcoblasts and becoming polymorphous. All the mature forms were killed, not only of *Amœba*, but of the *Nitzschia* associated with them. On the other hand, the sarcoblasts were numerous. Hence the fact, that the latter are able to undergo perfect and long-continued desiccation without destruction of their vitality, is conclusively established.

## EXPLANATION OF PLATE VIII.

The letters *c* and *n* respectively denote the contractile vesicle and nucleus in all the figures in which these organs are present.

*Figs.* 1 to 5 represent successive stages in the development of the young *Amœba* from a free sarcoblast.

*Fig.* 1. First stage, which dates from the evolution of the contractile vesicle *c*. The nucleus, if present at this period, is wholly obscured within the granular sarcoblast.

*Fig.* 2. Second stage, in which the sarcoblast has become considerably enlarged, chiefly through the dilation of the contractile vesicle, *c*. The nucleus, *n*, is now distinctly visible. Diameter of sarcoblast about $\frac{1}{1100}$th of an inch; of nuclear mass about $\frac{1}{9000}$th of an inch.

*Fig.* 3. Sarcoblast further enlarged, a second contractile vesicle, *c''*, adding greatly to its distention.

*Fig.* 4. Third stage. This marks the transition from the sarcoblast to the Amœban form. The spherical outline is now lost, owing to inordinate distention; and the primary contractile vesicle, *c*, performs its discharge for the first time.

*Fig.* 5. Fourth stage. Polymorphism has now commenced, and the villous appendage becomes rapidly formed by the repeated discharges of the contractile vesicles. Longest diameter of specimen about $\frac{1}{750}$th of an inch.

*Fig.* 6. The first stage in the development of the young *Amœba* from a free acapsular nucleus; contractile vesicle, *c*, just showing itself as in fig. 1. Diameter of mass $\frac{1}{1000}$th of an inch. No nuclear body visible within the body. Average diameter of component granules $\frac{1}{12000}$th of an inch.

*Fig.* 7. The same specimen as seen after the completion of the fourth stage of its development. The character of the acapsular nucleus is now entirely lost, through the diffusion of its component granules and the increase of the more hyaline protoplasm. Contractile vesicles (*c*) now in constant action. A nucleus, similar in all respects to that seen in the former specimens, is also present. Size now variable, and dependent on form assumed for the time being. When globular, about $\frac{1}{650}$th of an inch.

*Fig.* 8. An occasional variety of the kind shown in the last figure, in which the original acapsular nuclear mass (*n*) remains nearly entire, the ordinary minute encapsuled nucleus not being hitherto observable. *h*, a number of the large hexahedral crystalloids, varying from $\frac{1}{5500}$th to $\frac{1}{4500}$th of an inch in length. These crystalloids, however, are not confined to the specimens exhibiting the peculiar condition of the primary acapsular nucleus, but are occasionally to be met with in the ordinary young *Amœbæ*. Length of specimen about $\frac{1}{625}$th of an inch.

*Fig.* 9. A frequent form, in which the normal condition of the nucleus is shown, but the pseudopodia have temporarily assumed the tapering and pointed shape.

*Fig.* 10. *Amœba*-cyst from damp confervoid growths liable to desiccation, shown as it appears after immersion in water. Contractile vesicle (*c*) dilated, but unable to discharge in the usual manner. *s s*, sarcoblasts; *d*, an effete frustule of a diatom (*Nitzschia amphioxys*). Diameter of cyst about $\frac{1}{200}$th of an inch.

*Fig.* 11. Remarkable quiescent state of *Amœba villosa*, in which the surface is covered with more or less rigid, short, tapering pseudopodia of an Actinophryan character. Length, as seen in figure, about $\frac{1}{700}$th of an inch. Diameter of nuclear capsule $\frac{1}{3330}$th of an inch; of nucleus $\frac{1}{4500}$th.

*Figs.* 12 to 15 represent successive stages in the encystation of *Amœba*.

*Fig.* 12. A specimen becoming quiescent, after having incepted a large *Pinnularia* and thrown off all other extraneous substances,—the nucleus and its capsule being either absorbed, rendered invisible amongst the granules, or entering partly into the composition of the granular mass, of which the entire body now seems to consist. Some large oil-globules are shown within the diatom-frustule; *c*, minute contractile vesicles, the action of which is almost wholly suspended.

*Fig.* 13. The same form, showing the Actinophryan pseudopodia retracted, and the margin of the body rapidly becoming smooth and oblong.

*Fig.* 14. The membranous *Amœba*-cyst now complete, the granular particles of which the substance of the body was composed having become segregated into masses which take the form of sarcoblasts.

*Fig.* 15. The contents of the *Amœba*-cyst have now almost entirely disappeared, but within the dehiscent valves of the diatoms are to be seen the sarcoblasts. This last condition is, comparatively, of rare occurrence. The average length of the four specimens here delineated was about $\frac{1}{250}$th of an inch.

*Fig.* 16. Test of *Difflugia pyriformis*, var. *symmetrica* (Wall.), showing symmetrical arrangement of the crystalline plates.

*Fig.* 17. Group of minute *Amœba*, each developed from a single granule of a disrupted acapsular nucleus, and under no circumstances ciliated. In each is to be seen a villous appendage, contractile vesicle, and nuclear spot. Length from $\frac{1}{3330}$th to $\frac{1}{1660}$th of an inch.

*Fig.* 18. *Amœba* engaged in tearing pieces out of an *Actinophrys* by means of its pseudopodia. *f, v,* food-vacuole containing a mass so torn off.

N.B.—These figures, although originally drawn to one uniform scale, are only uniform here as regards the relative proportions of the structure in each example, since it became necessary to modify the size of the various figures in order to accommodate them in a single plate. I would avail myself of the opportunity, however, to express my conviction that variation in the dimensions of the Rhizopods generally is so great, and so dependent on purely accidental conditions—that is to say, on conditions involving no physiological difference in the animal—that they ought to be allowed no greater weight in an attempt at classification than the variation in the length of a blade of grass or the height of a thistle.

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*Erratum in Dr. Wallich's paper contained in the November Number of 'The Annals.'*

Page 335, fifteenth line from bottom, for "*Chilodontes*" read "Chilodons."

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## PROCEEDINGS OF LEARNED SOCIETIES.

### ZOOLOGICAL SOCIETY.

Feb. 24, 1863.—E. W. H. Holdsworth, Esq., in the Chair.

### On a New Genus and Species of Leaf-nosed Bats in the Museum at Fort Pitt. By Robert F. Tomes.

In a collection of Bats preserved in spirit, and forming part of the Museum at Fort Pitt, Chatham, which has been submitted to my examination by Dr. Sclater, is one which constitutes a new and well-marked genus of the *Phyllostomidæ*, or Leaf-nosed Bats of the New World. It is more nearly allied to the genus *Macrotis* than to any other; but differs from it, among other respects, in having its lance-shaped nose-leaf developed to an enormous extent. I characterize and name it as follows:—

Lonchorhina, gen. nov.

*Top of the head somewhat elevated; face depressed; facial crests complicated, consisting of a very long and pointed posterior leaf, in front of which are two pits, more or less surrounded by prominent fleshy excrescences; lower lip with a smooth triangular space in front; ears long and broad; longest finger with four phalanges; wing-membrane extending to the distal extremity of the tibia, and attached to the* os calcis*; tail extending to the whole length of the interfemoral membrane, as in the genera* Macrotis *and* Vespertilio.

The posterior lanceolate facial leaf is in this Bat of great length, being fully as long as the head of the animal; it is pointed, and has